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RECENT DEVELOPMENTS IN THE MINING INDUSTRY

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I have been asked to speak briefly about recent progress in the mining industry of the United States, and to touch on the general advancement of engineering science as applied to mining.

By recent, I shall mean within the past 20 or 30 years. Such a period includes a great many of the changes which are of particular interest to the present generation of engineers, and the undergraduates of today will hardly turn back farther than the beginning of the present century in their study of development of methods and processes. Also, my own professional life spans this period, and I have seen or have been aware of most of these developments as they were taking place.

In my review of developments, for the sake of simplicity and clarity, I shall deal separately with improvements in metal mining, coal mining, mechanical and electrical machinery for mines, metallurgy, petroleum engineering, and safety practices. Under each of these headings I have set down what appear to me to be the outstanding changes brought about during the past 2 or 3 decades. Other points will occur to other engineers; I do not represent that the following review is complete; it is only intended to be suggestive.

In general, improvements in mining and metallurgical practices have come gradually, the changes being effected little by little, simultaneously in widely scattered places, and through the experience and inventive genius of many men. These changes have had small beginnings, and are generally the cumulative result of many steady and unsensational progressions, which still continue. What we today might be inclined to consider the culmination of a series of betterments in mining is, of course, but an instantaneous phase of developments which will continue in the future at even a more rapid pace than they have in the past. We are looking at but a flash of a moving picture, with an endless reel to come after we finally leave the theatre.

Behind all the changes in the mineral industry, the driving force has been the increasing demand of an expanding population for more metals and minerals with which to advance civilization. More people, with an increasing per capita consumption, together with the exhaustion of the richer but smaller, and more

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accessible mineral deposits, have required that the engineer exploit faster and on a larger scale the lower-grade but more extensive reserves. To do this at reasonable cost has taxed his ingenuity in every direction. Advancing costs of labor, materials, and supplies, have necessitated improvements and refinements in practices, so a unit of metal or mineral may be produced with less labor and with fewer operating supplies. Better coordination and direction of work, elimination of duplication and other waste, and the multiplication of the work done per unit of man or other power, are means toward this end. In America, this is all indicated by the so-called "speeding up process", whereby it appears that the average workman in the United States now puts out 30 times as much as the average man in China, Russia, or India, almost 14 times more than the native of Italy or Japan, 8 times as much as the worker in Poland, more than 3 times as much as the native of France or Australia, 2½ times as much as the German, nearly two-thirds more than the workman of Great Britain, and almost one-half more than the Canadian who is our nearest rival. Here we have the apparent anomaly of high wages and low costs, and this is important to remember in considering our mining industry. Bearing this general picture in mind, we may now turn to certain more concrete considerations.

In reviewing changes in metal mining, let us first consider the case of copper. From 50 years ago until the World War, the average price of this metal was 14½¢ per lb.; during the war the average was 24¢, and since 1919 it has been 13.6¢, or less than the pre-war price. High war prices, coupled with urgent requests from the Allied Governments, resulted in production being pushed to a maximum, without much regard for the physical condition of the mines or the maintenance of proper ore-reserves. The period from the beginning of the century to the first days of the war had witnessed the start and growth of operations at the large low-grade so-called porphyry properties, in which new methods of surface and underground mining had been developed. In the mines, shrinkage-stope, top-slice, and various other caving methods were employed. That was a time of steady and orderly improvement in mining methods. Then came the war and the scramble for rapid production even at the cost of proper engineering practices; the result was a large copper output, but the end of the war, followed by a great drop in price of the metal, found higher-grade deposits depleted, mines and equipment strained or exhausted, wages and materials costly; the operator, to survive, had to turn at once to lower-grade deposits, which he was forced to work at decreased cost to meet low copper prices; against him were arrayed all the unfavorable factors enumerated above. Then came rapid readjustments and changes in methods, with the result that the American copper producer increased tonnages mined per man-shift, reduced costs by decreasing consumption of explosives, power, timber, and other supplies, and thus weathered the storm.

The producers of other metals went through more or less similar experiences, and the remarkable thing about it all is the way in which American mining engineers met increased labor and supply costs and low metal prices by ingenious methods for decreasing production costs.

Metal mining in the United States might be briefly reviewed by saying that the art was born in California in the early 1850's; took a long forward step in the 60's, when extraction from wide rich lodes in Virginia City, Nev., necessitated square-setting and filling instead of irregular timbering; progressed

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through the period when hand-steel miners carefully selected the smaller and higher-grade portions of veins, blasted them down on rawhides or canvas, carefully picked, sorted, and sacked the ore won in overhand stopes, waste-filled as in the common European method; then came machine drills, shrinkage, pillar, and similar stoping methods, top-slicing, caving, and finally block-caving and branch-raise methods as used in some of the big mines of today.

I can summarize what has been accomplished in mining no more forcefully than by giving a few illustrations of improved practice: One copper mine in Arizona produced 7½ tons of ore per man-shift in 1916; 8⅓ tons in 1917; and almost 17 tons in 1926, with a dynamite-consumption of 1/3 of a lb. per ton. Another Arizona copper mine increased its per-man-shift production from 4½ tons in 1925 to 10½ tons in 1926. An open-cut copper mine in Utah produced 11 tons per man-shift in 1911, and by 1926, working with lower-grade ore, the production had been increased to 28¼ tons per man-shift. Only 1/10 of a lb. of explosives per ton was used. The average daily ore-output was nearly 47,000 tons. To meet high labor and supply-costs, a gold mine in Alaska so improved its mining methods that over a period of years it has produced 47 tons per man-shift, using an average of only ¼ of a lb. of explosives per ton of ore.

These are examples of the best American engineers have done but not the best they will do. Nowhere else in the world have such results been even approximated, except at American-operated mines in Chile.

In considering bituminous coal mining, it should be remembered that under-cutting machines, replacing hand-picks, were first introduced about 1890, and that from 1890 to 1924 the average production per man per day had risen from about 2½ to over 4½ tons. Contemporaneously, the percentage of coal produced by under-cutting has risen from nothing to about 70% of the total coal mined. Other factors enter into this increase in each miner's productivity, but it is generally considered that under-cutting machines have, in the case of bituminous coal, increased the output per man-shift by at least 50%. Shooting off the solid in bituminous mines is steadily decreasing and is now restricted to about 11% of our total production.

Coal-loading machines are being rapidly installed, the quantity loaded having increased five-fold since 1923. The tonnage loaded by machines, however, (10,022,000 tons in 1926) is still barely two per cent of the total production, and thus, while their introduction is an interesting development and one which may later have greater effects than are now apparent, their use can hardly yet be classed as an important element in coal production. I myself installed electrically-driven mechanical conveyors at long-wall faces in European coal mines in 1913, but the use of such conveyors has come more recently in this country.

We have lived to see electricity largely supplant steam and compressed air underground. The mule is disappearing from the mines, and the operations equipped with electric haulage now produce 86% of the total output. Concrete is coming to be used largely, and in the past 25 years has replaced other materials for the construction of overcasts, stoppings, and mine-portals. Steel tipples on concrete foundations now replace wooden structures on masonry footings. Roller bearings on mine-car wheels make transport easier, and solid-body cars

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handled by rotary-dumping devices are displacing end or side-gate cars. The panel system of mining, whereby large coal mines are opened by independent units, is making progress. Thirty years ago a 2000-ton mine was a large producer, whereas today operations are tending toward a larger-unit basis, so that 5,000 to 10,000-ton mines are now not uncommon. Coal-cleaning is now receiving increased attention, and many refinements are finding their way into current bituminous coal mining practice.

Anthracite coal mining at first sight seems to present a less favorable picture, for in the same period of 30 years the production per man-shift has only increased from 1.85 to 2.10 tons; there has been steady progress in engineering but the natural conditions have grown vastly more difficult. In the last generation, the average depth of workings has increased 77% and the average thickness of the beds is barely half what it once was. The volume of water to be handled has greatly increased and many collieries have been driven from virgin coal to second or even third mining. The anthracite engineers have increased the percentage of recovery from as low as 40% in 1880 to a present average of 65%. These advances have been made possible by steady improvements in equipment, particularly the general introduction of electricity. Natural conditions have limited the use of cutting machines to about 2% of the output, but in the adoption of face conveyors the anthracite mines are ahead of the bituminous.

Especially significant has been the progress in anthracite preparation, through increasing size of the breakers and the introduction of new methods of both wet and dry-cleaning of coal. Sales of the small sizes (including pea) have been built up from 23% of the shipments in 1890 to 35% in 1925.

In regard to general changes in mechanical practices at mines, I have before mentioned the increasing use of electricity. Electric power is now often brought from a distance, and there are fewer local fuel-burning plants; the flexibility of distribution of electric power is recognized. Electricity is used from the surface to the mine-face in coal mining, but no successful electrically-operated drill has been developed for use in metal mines, where rock-drills operated by compressed air still prevail. Hand-drilling in metal mines has gone out of fashion during my time, and the tendency in air-drills has been toward lighter and more powerful one-man drills; the heavy two-man drill of twenty years ago is now seldom seen. Leading machines frequently replace hand-shoveling in underground mines, and electric haulage is becoming more common; underground conveyors and mechanical scrapers are frequently used. Steam is still used for hoisting in most deep metal mines, while hoisting by electricity is being more used in shallow or medium-depth mines. Large-capacity centrifugal pumps, operating against high heads, are replacing reciprocating pumps. Huge steam or electric shovels have improved open-pit metal mining results and made possible many of our large-tonnage operations. At one strip-pit in Montana the output of coal per man per day is 47 tons, or ten times the average in the underground mines. Even the mine blacksmith and machine shops have been revolutionized in the past 30 years; drill-steel is now sharpened by machinery, and delicate instruments control heat-treatments which make old-time tempering processes appear extremely crude. All mechanical equipment is now faster-moving than heretofore; higher speeds are noted in devices such as steam turbines, electric motors, turbine air-compressors, and centrifugal pumps. Oil engines for larger installations and gasoline engines for smaller plants are often seen at

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metal mines, replacing old wood-fired boilers. The mechanical equipment of all classes of mines is becoming more complex, and more skilled labor and better technical supervision are required.

In touching on recent progress in metallurgy, it should be borne in mind that mining and metallurgical developments are so intimately related that they are but component parts of the general movement toward improvement in the mineral industry. If advance in metallurgical methods had not been steadily maintained, progress in the art of mining would have been correspondingly curtailed. So dependent is our present civilization on metals, and so closely is our social progress interwoven with metallurgical achievement, that one can hardly discuss the advance of the art of metallurgy without dealing with the broader topic of the advance of mankind.

Within economic limitations, recent developments in ferrous metallurgy tend either toward increased quantity or improved quality. The former is the case with the iron blast-furnace, where by increasing the size and the mechanical perfection of the apparatus, greatly increased outputs have been attained; the same tendency is seen all the way to the open-hearth-steel plant. Quality products such as new alloys or compounds having special properties, are increasingly in demand and exert industrial influences all out of proportion to their weight or volume. Iron alloys containing tungsten, chromium, molybdenum, cobalt, nickel and vanadium have all become of tremendous industrial importance since the beginning of this century; new methods of heat-treatment are also noteworthy.

In the non-ferrous field, various forms of water-concentration were in use at the beginning of the century. Sluices, buddles, jogs, vanners, tables and other forms of equipment were in general use for concentration or separation of various minerals. Then, less than 20 years ago, came flotation, that new magic of many variations; today more than three-fourths of our non-ferrous ore is treated by this method. This single improvement has made usable such vast tonnages of low-grade or complex deposits, that an equivalent to a very large increase in our natural resources has been accomplished, and we are assured of large supplies of relatively cheap metals for a long time to come.

In the extraction of precious metals such as gold and silver, simple concentrating processes gave way to amalgamation, and this method in turn became relatively unimportant with the development of the cyanide process, which, although first patented in 1887, has been largely improved within the past 3 decades, so that modern practice has resulted in higher extraction at lower cost by saving both cyanide and precipitants.

In the fire-metallurgy of lead, preparation of the fine portion of the blast-furnace charge by sintering; saving of volatilized products by baghouse or electric precipitator; and better refining methods for lead bullion, are outstanding achievements.

Zinc metallurgy shows even greater advances. The retort, in which all zinc was produced until the World War, now has the electrolytic plant as a growing rival; in 1926, about 18% of the total new zinc was produced by the electrolytic process. The success of electrolytic zinc is due to the success of flotation in

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making rich zinc concentrates from complex ores; to the ease of handling residual products; and to the constant demand for processes involving less human labor. Improvements of retort-smelting have been few. More complete removal of the sulphur from the charge by roasting; the use of higher temperatures and of alloys to resist them; and the employment of sintering are typical betterments in retort-practice.

The reclaiming of various metals that have once been used, is receiving much attention; the necessity for this has been generally recognized only of late years.

Copper metallurgy was probably improved more by the application of the Bessemer process to the treatment of copper matter, than by any other single change; after this we might list processes involving electrolysis. The great acid-leaching plants for oxidized ores, in which the dissolved copper is precipitated electrolytically, come at once to mind in considering late developments. Ammonia is also being used commercially as a solvent for copper.

The use of electricity in metallurgy has increased rapidly during the period in question; it has been applied to the refining of copper, lead, and the precious metals, as well as more recently to the metallurgy of zinc; the ferro-alloys were largely developed in the electric furnace, and in past years tin has been electrolytically refined. Aluminum is almost entirely a product of the electric furnace; the alkaline-earth metals and their alloys are other examples.

The last subdivision of the mineral industry with which I will deal is the production and treatment of petroleum. Here one of the outstanding achievements is the development of the cracking process, whereby gasoline and other volatile products can be won by cracking the heavier oils; this process was not used on a large scale until 1913, in which year a few thousand gallons were produced; in 1927, over 4¼ billions of gallons of gasoline were thus produced, or about 30% of the gasoline output of United States refineries for that year. Thus the automobiles are kept running without undue destruction of crude oil; if only straight distillation had been used in 1927, 426 million additional barrels of crude oil would have been run to the stills to produce the gasoline required, so this figure of 426 million barrels represents the crude oil actually conserved last year by the development of the cracking process. In this automotive age, this is indeed a noteworthy betterment.

Another important change is the development of methods for recovering gasoline from natural gas. The first commercial plants to recover gasoline from this source were built about 1910. In 1911, 7½ million gallons of gasoline were thus produced, whereas in 1927 this had increased to well over 1½ billion gallons, or 12% of the total gasoline production for that year. This extremely volatile product is especially valuable for blending with heavier gasoline and naptha for the manufacture of motor fuel, thus making usable large quantities of the heavier products which could not have been used in automotive engines without the addition of this lighter ingredient.

Rotary drilling was first used in 1896, in Texas, and this method made possible the penetration of caving formations which could not have been drilled

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with cable tools, and thus enabled the drillers to develop important oil fields on the Gulf Coast and in California. Prolific deep sands, far below the surface and overlain with strata not standing well enough for cable-tool equipment, can now be reached with the rotary drill. This development has thus added largely to our supply of crude oil.

The last improvement in petroleum technology I will mention is the development of methods for increasing the recovery from oil-sands. This innovation only dated back to 1903, when gas under pressure was forced into an oil well, and, after the pressure was released, it was found that the productivity of the well had been materially increased. As a result, older fields in Pennsylvania, West Virginia, Ohio, and Oklahoma are today being re-pressured with gas or air, and marked increases in production are thus effected.

I cannot leave the subject of recent progress in the mining industry without touching briefly on the safety movement which is receiving so much attention from thoughtful men. Since the beginning of this century, permissible explosives have come into use in coal mines, and today about 1/3 of our coal is produced by them. The recognition of the explosibility of coal-dust, and the introduction of rock-dusting in bituminous coal mines mark another great stride toward safety. The introduction of permissible electric equipment is an important step in coal mining, although as yet only about 1/3 of our equipment is of permissible character. The wide use of the electric cap-lamp has come within our era, and electric blasting is another important safety feature. The use of water on cutter-bars, steel-housed ventilating fans, and other devices are significant changes. The spread of workman's compensation acts has hastened the advance of safety measures in both coal and metal mines.

Within the period under review, safety and health conditions in metal mines have generally improved. Ventilation is given more attention; dust problems are dealt with by wet drilling and other practices. The use of low-freezing explosives is a step in the right direction, and the practice of blasting only at the end of the shift is a comparatively new development. Concrete, cement mixtures, and structural steel underground have increased safety; multiplying the number of exits has diminished fatalities; better trolley-wire protection and the improved use of electricity generally, have assisted in bringing about safer conditions.

Many and various as are the subjects I have touched upon to indicate progress in the mining industry within less than 1/3 of a century, yet the list as I have given it is incomplete; however, even this rough outline shows the astonishing changes that have come within the professional lives of many of us, and it may serve to suggest to the young engineers and undergraduates here the progress that may be expected in the next 3 decades. No one doubts that changes in a given period of time to come will be greater and more important than in an equal time that has passed. To be prepared to keep abreast with such changes requires the most thorough technical training in the preparation of the young American engineer for the problems that are before him--problems that are increasing in variety and complexity and which will tax him to the utmost even though he be well prepared and ready, forceful and of good courage.

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